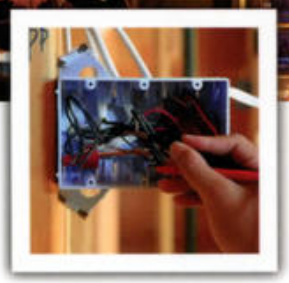
Mike Holt's Illustrated Guide to

Understanding the NATIONAL ELECTRICAL CODE®

Volume 1 • Articles 90 - 480



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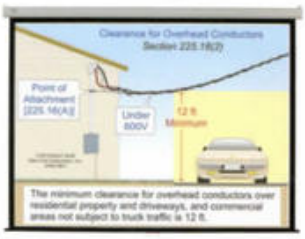

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Understanding the NATIONAL ELECTRICAL CODE®

Volume 1 • Articles 90 - 480

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Lord Jesus Christ,
my mentor and teacher.
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Introduction

Mike Holt's Illustrated Guide to Understanding the National Electrical Code, Volume 1

This edition of *Mike Holt's Illustrated Guide to Understanding the National Electrical Code, Volume 1* textbook is intended to provide you with the tools necessary to understand the technical requirements of the *National Electrical Code (NEC)®*. The writing style of this textbook, and in all of Mike Holt's products, is meant to be informative, practical, useful, informal, easy to read, and applicable for today's electrical professional. Just like all of Mike Holt's textbooks, this textbook contains hundreds of full-color illustrations to help you see the safety requirements of the *NEC* in practical use, helping you visualize the Code in today's electrical installations.

This illustrated textbook contains cautions regarding possible conflicts or confusing *Code* requirements, tips on proper electrical installations, and warnings of dangers related to improper electrical installations. In spite of this effort, some rules may seem to be unclear or need additional editorial improvement.

This textbook can't eliminate confusing, conflicting, or controversial *Code* requirements, but we do try to put these requirements into sharper focus to help you understand their intended purpose. Sometimes a requirement is so confusing nobody really understands its actual application. When this occurs, we'll point the situation out in an up-front and straightforward manner. We apologize in advance if that ever seems disrespectful, but our intention is to help the industry understand the current *NEC* as best as possible, point out areas that need refinement, and empower *Code* users to be a part of the process of change to create a better *NEC* for the future.

The *NEC* is updated every three years to accommodate new electrical products and materials, changing technologies, improved installation techniques, and make editorial improvements to improve readability. While the uniform adoption of each new edition of the *Code* is the best approach for all involved in the electrical industry, many inspection jurisdictions modify the *NEC* when it's adopted. To further complicate this situation, the *Code* allows the authority having jurisdiction (AHJ) the authority to waive *NEC* requirements or permit alternative wiring methods contrary to *Code* requirements. This is only allowed when the completed electrical installation is assured to provide an equivalent level of safety [90.4].

Keeping up with requirements of the *NEC* should be the goal of everyone involved in the safety of electrical installations. This includes electrical installers, contractors, owners, inspectors, engineers, instructors, and others concerned with electrical installations.

About the 2011 *NEC*

The actual process of changing the *Code* takes about two years, and it involves thousands of individuals making an effort to have the *NEC* as current and accurate as possible. Let's review how this process works:

Step 1. Proposals—November, 2008. Anybody can submit a proposal to change the *Code* before the proposal closing date. Over 5,000 proposals were submitted to modify the 2011 *NEC*. Of these proposals, over 300 rules were revised that significantly effect the electrical industry. Some changes were editorial revisions, while others were more significant, such as new articles, sections, exceptions, and Informational Notes.

Step 2. *Code*-Making Panel(s) Review Proposals—January, 2009. All *Code* proposals were reviewed by *Code*-Making Panels. There were 19 panels in the 2011 *Code* process who voted to accept, reject, or modify them.

Step 3. Report on Proposals (ROP)—July, 2009. The voting of the *Code*-Making Panels on the proposals was published for public review in a document called the "Report on Proposals," frequently referred to as the "ROP."

Step 4. Public Comments—October, 2009. Once the ROP was available, public comments were submitted asking the *Code*-Making Panel members to revise their earlier actions on change proposals, based on new information. The closing date for "Comments" was October, 2009.

Step 5. Comments Reviewed by *Code* Panels—December, 2009. The *Code*-Making Panels met again to review, discuss, and vote on public comments.

Step 6. Report on Comments (ROC)—April, 2010. The voting on the "Comments" was published for public review in a document called the "Report on Comments," frequently referred to as the "ROC."

Step 7. Electrical Section—June, 2010. The NFPA Electrical Section discussed and reviewed the work of the *Code*-Making Panels. The

Electrical Section developed recommendations on last-minute motions to revise the proposed *NEC* draft that would be presented at the NFPA annual meeting.

Step 8. NFPA Annual Meeting—June, 2010. The 2011 *NEC* was voted by the NFPA members to approve the action of the *Code*-Making Panels at the annual meeting, after a number of motions (often called "floor actions") were voted on.

Step 9. Standards Council Review Appeals and Approves the 2011 *NEC*—July, 2010. The NFPA Standards Council reviewed the record of the *Code*-making process and approved publication of the 2011 *NEC*.

Step 10. 2011 *NEC* Published—September, 2010. The 2011 *National Electrical Code* was published, following the NFPA Board of Directors review of appeals.

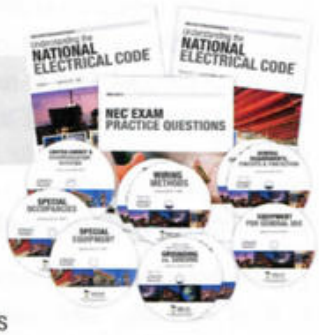
> **Author's Comment:** Proposals and comments can be submitted online at the NFPA Website (www.nfpa.org). From the homepage, click on "Codes and Standards" at the top of the page, then from the Codes and Standards page click on "Proposals and Comments" in the box on the right-hand side of the page. The deadline for proposals to create the 2014 *National Electrical Code* is November 5, 2011. If you would like to see something changed in the *Code*, you're encouraged to participate in the process.

The Scope of this Textbook

This textbook, *Understanding the National Electrical Code, Volume 1,* covers the general installation requirements that Mike considers to be of critical importance in Articles 90 through 480 (*NEC* Chapters 1 through 4). This textbook is written with these stipulations:

- **Power Systems and Voltage.** All power-supply systems are assumed to be solidly grounded ac such as: 120V single-phase, 120/240V single-phase, 120/208V three-phase, 120/240V three-phase, or 277/480V three-phase, unless identified otherwise.
- **Electrical Calculations.** Unless the question or example specifies three-phase, the questions and examples are based on a single-phase power supply.
- **Rounding.** All calculations are rounded to the nearest ampere in accordance with 220.5(B).
- **Conductor Material.** All conductors are considered copper, unless aluminum is identified or specified.
- **Conductor Sizing.** All conductors are sized based on a THHN copper conductor terminating on a 75°C terminal in accordance with 110.14(C)(1), unless the question or example identifies otherwise.
- **Overcurrent Device.** The term "overcurrent device" in this textbook refers to a molded case circuit breaker, unless identified otherwise. If a fuse is identified in the text, it's to be of the single-element type, also known as a "one-time fuse," unless identified otherwise.

Mike Holt's Detailed *NEC* Library



If you want to really understand the 2011 *National Electrical Code,* then Mike Holt's Detailed *Code* Library is ideal for you. This program covers general installation requirements, branch circuits, feeders, services and overcurrent protection, grounding and bonding, conductors, cables and raceways, boxes, panels, motors, transformers, and much more. Summary questions are included in all books to help you test your knowledge.

This program includes 3 textbooks and 10 DVDs:

- *Understanding the National Electrical Code Volume 1* textbook
- *Understanding the National Electrical Code Volume 2* textbook
- *NEC Exam Practice Questions* book
- General Requirements Part 1 DVD and Part 2 DVD
- Grounding vs. Bonding Part 1 DVD and Part 2 DVD
- Wiring Methods Part 1 DVD and Part 2 DVD
- Equipment for General Use DVD
- Special Occupancies DVD
- Special Equipment DVD
- Limited Energy and Communication Systems DVD

Order Mike Holt's Detailed *Code* Library by calling 888.NEC.CODE (632.2633) or visiting www.MikeHolt.com

What is the QR code above? See page xviii.

About This Textbook

This textbook is to be used along with the *NEC*, not as a replacement for it, so be sure to have a copy of the 2011 *National Electrical Code* handy. Compare what Mike is explaining in this book to what the *Code* book says, and discuss any topics that you find difficult to understand with others.

You'll notice that in this book, a great deal of the *NEC* wording has been paraphrased, and some of the article and section titles appear different from the wording in the actual *Code*. Mike believes doing so makes it easier to understand the content of the rule, so keep this in mind when comparing this textbook against the actual *NEC*.

We hope that as you read through this textbook, you'll allow sufficient time to review the text along with the outstanding graphics and examples, which are invaluable to your understanding.

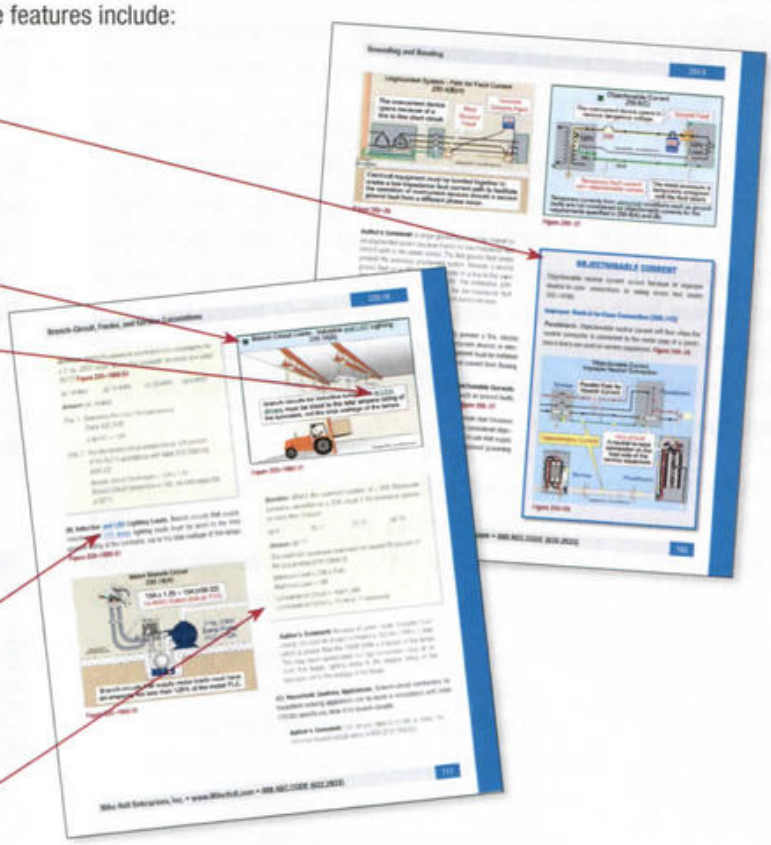
Textbook Format

This textbook follows the *NEC* format, but it doesn't cover every *Code* requirement. For example, it doesn't include every article, section, subsection, exception, or Informational Note. So don't be concerned if you see the textbook contains Exception 1 and Exception 3, but not Exception 2.

Important Features for the 2011 Edition of This Textbook

In order to better meet the needs of our customers, we have improved the layout of this textbook with some new feaures, in addition to the features from the 2008 edition which were so successful. These features include:

- Special Sections which contain additional information to better help you understand a concept are identified with a light gray background and colored frame.
- Graphics that contain a 2011 *Code* change will have a green border with a green 2011 CC icon next to the heading.
- Any *NEC* changes will be in green underlined text in all graphics. If you see a green bordered graphic with no green underlined text, it most likely indicates that the *Code* change is the removal of some text. Graphics without a color border support the concept being discussed, but nothing in the graphic was affected by a change for 2011.
- Any 2011 *Code* is denoted by underlined text and in the corresponding chapter color. For example, in Chapter 1 the change text will be red and underlined; Chapter 2 the change text will be cyan and underlined, and so on.
- Examples or practical application questions with their answer and solution have a light yellow background.



Cross-References and Author's Comments

Cross References. This textbook contains several *NEC* cross-references to other related *Code* requirements to help you develop a better understanding of how the *NEC* rules relate to one another. These cross-references are indicated by *Code* section numbers in brackets, an example of which is "[90.4]."

Author's Comments. "Author's Comments," written by Mike, are intended to help you understand the *NEC* material, and to bring to your attention things of which you should be aware.

Difficult Concepts

As you progress through this textbook, you might find that you don't understand every explanation, example, calculation, or comment. Don't become frustrated, and don't get down on yourself. Remember, this is the *National Electrical Code* and sometimes the best attempt to explain a concept isn't enough to make it perfectly clear. If you're still confused, visit www.MikeHolt.com, and post your question on the *Code* Forum for help.

Different Interpretations

Some electricians, contractors, instructors, inspectors, engineers, and others enjoy the challenge of discussing the *NEC* requirements, hopefully in a positive and productive manner. This give-and-take is important to the process of better understanding the *Code* requirements and application. However, if you're going to get into an *NEC* discussion, please don't spout out what you think without having the actual *Code* book in your hand. The professional way of discussing an *NEC* requirement is by referring to a specific section, rather than talking in vague generalities.

QR Codes

QR Code

What is this? It is a QR Code and gives you the ability to use your smartphone to take a photo (using a barcode reader app) and be directed to a website. For example, the QR Code to the left when captured will direct your smartphone to the Mike Holt Enterprises website. We have included these in various places in our book to make it easier for you to go directly to the website page referenced. In order to use a QR code, you will need an app for your phone that allows your phone to read this barcode. Your phone may already have the ability to scan this barcode, but if not visit the website www.mobile-barcodes.com/qr-code-software for more information.

Textbook Errors and Corrections

Humans develop the text, graphics, and layout of this textbook, and since currently none of us are perfect, there may be a few errors. This can occur because the *NEC* is dramatically changed each *Code* cycle; new articles are added, some are deleted, some are relocated, and many are renumbered. We take great care in researching the *NEC* requirements to ensure this textbook is correct. If you believe there's an error of any kind in this textbook (typographical, grammatical, technical, or anything else), no matter how insignificant, please let us know.

Any errors found after printing are listed on our Website, so if you find an error, first check to see if it's already been corrected. Go to www.MikeHolt.com, click on the "Books" link, and then the "Corrections" link (www.MikeHolt.com/bookcorrections.htm).

If you don't find the error listed on the Website, contact us by sending an E-mail to Corrections@MikeHolt.com. Be sure to include the book title, page number, and any other pertinent information.

You Tube

Visit the Mike Holt channel on YouTube to see video clips that accompany this and our other 2011 books (www.youtube.com/user/MikeHoltNEC).

How to Use the *National Electrical Code*

The *National Electrical Code* is written for persons who understand electrical terms, theory, safety procedures, and electrical trade practices. These individuals include electricians, electrical contractors, electrical inspectors, electrical engineers, designers, and other qualified persons. The *Code* isn't written to serve as an instructive or teaching manual for untrained individuals [90.1(C)].

Learning to use the *NEC* is like learning to play the game of chess; it's a great game if you enjoy mental warfare. When learning to play chess, you must first learn the names of the game pieces, how the pieces are placed on the board, and how each piece moves.

Once you understand the fundamentals, you're ready to start playing the game. Unfortunately, at this point all you can do is make crude moves, because you really don't understand how all the information works together. To play chess well, you'll need to learn how to use your knowledge by working on sub-tle strategies before you can work your way up to the more intriguing and complicated moves.

Not a Game

Electrical work isn't a game, and it must be taken very seriously. Learning the basics of electricity, important terms and concepts, as well as the basic layout of the *NEC* gives you just enough knowledge to be dangerous. There are thousands of specific and unique applications of electrical installations, and the *Code* doesn't cover every one of them. To safely apply the *NEC*, you must understand the purpose of a rule and how it affects the safety aspects of the installation.

NEC Terms and Concepts

The *NEC* contains many technical terms, so it's crucial for *Code* users to understand their meanings and their applications. If you don't understand a term used in a *Code* rule, it will be impossible to properly apply the *NEC* requirement. Be sure you understand that Article 100 defines the terms that apply to two or more *Code* articles. For example, the term "Dwelling Unit" is found in many articles; if you don't know what a dwelling unit is, how can you apply the requirements for it?

In addition, many articles have terms unique for that specific article and definitions of those terms are only applicable for that given article. For example, Section 250.2 contains the definitions of terms that only apply to Article 250—Grounding and Bonding.

Small Words, Grammar, and Punctuation

It's not only the technical words that require close attention, because even the simplest of words can make a big difference to the application of a rule. The word "or" can imply alternate choices for equipment wiring methods, while "and" can mean an additional requirement. Let's not forget about grammar and punctuation. The location of a comma can dramatically change the requirement of a rule.

Slang Terms or Technical Jargon

Electricians, engineers, and other trade-related professionals use slang terms or technical jargon that isn't shared by all. This makes it very difficult to communicate because not everybody understands the intent or application of those slang terms. So where possible, be sure you use the proper word, and don't use a word if you don't understand its definition and application. For example, lots of electricians use the term "pigtail" when describing the short conductor for the connection of a receptacle, switch, luminaire, or equipment. Although they may understand it, not everyone does.

NEC Style and Layout

Before we get into the details of the *NEC*, we need to take a few moments to understand its style and layout. Understanding the structure and writing style of the *Code* is very important before it can be used and applied effectively. The *National Electrical Code* is organized into ten major components.

1. Table of Contents
2. Article 90 (Introduction to the *Code*)
3. Chapters 1 through 9 (major categories)
4. Articles 90 through 840 (individual subjects)
5. Parts (divisions of an article)
6. Sections and Tables (*Code* requirements)

7. Exceptions (*Code* permissions)
8. Informational Notes (explanatory material)
9. Annexes (information)
10. Index

1. Table of Contents. The Table of Contents displays the layout of the chapters, articles, and parts as well as the page numbers. It's an excellent resource and should be referred to periodically to observe the interrelationship of the various *NEC* components. When attempting to locate the rules for a particular situation, knowledgeable *Code* users often go first to the Table of Contents to quickly find the specific *NEC* Part that applies.

2. Introduction. The *NEC* begins with Article 90, the introduction to the *Code*. It contains the purpose of the *NEC*, what's covered and what isn't covered along with how the *Code* is arranged. It also gives information on enforcement and how mandatory and permissive rules are written as well as how explanatory material is included. Article 90 also includes information on formal interpretations, examination of equipment for safety, wiring planning, and information about formatting units of measurement.

3. Chapters. There are nine chapters, each of which is divided into articles. The articles fall into one of four groupings: General Requirements (Chapters 1 through 4), Specific Requirements (Chapters 5 through 7), Communications Systems (Chapter 8), and Tables (Chapter 9).

Chapter 1 General
Chapter 2 Wiring and Protection
Chapter 3 Wiring Methods and Materials
Chapter 4 Equipment for General Use
Chapter 5 Special Occupancies
Chapter 6 Special Equipment
Chapter 7 Special Conditions
Chapter 8 Communications Systems (Telephone, Data, Satellite, Cable TV and Broadband)
Chapter 9 Tables–Conductor and Raceway Specifications

4. Articles. The *NEC* contains approximately 140 articles, each of which covers a specific subject. For example:

Article 110 General Requirements
Article 250 Grounding and Bonding
Article 300 Wiring Methods
Article 430 Motors and Motor Controllers
Article 500 Hazardous (Classified) Locations
Article 680 Swimming Pools, Fountains, and Similar Installations
Article 725 Remote-Control, Signaling, and Power-Limited Circuits
Article 800 Communications Circuits

5. Parts. Larger articles are subdivided into parts.

Because the parts of a *Code* article aren't included in the section numbers, we have a tendency to forget what "part" the *NEC* rule is relating to. For example, Table 110.34(A) contains working space clearances for electrical equipment. If we aren't careful, we might think this table applies to all electrical installations, but Table 110.34(A) is located in Part III, which only contains requirements for "Over 600 Volts, Nominal installations." The rules for working clearances for electrical equipment for systems 600V, nominal, or less are contained in Table 110.26(A)(1), which is located in Part II—600 Volts, Nominal, or Less.

6. Sections and Tables.

Sections. Each *NEC* rule is called a "*Code* Section." A *Code* section may be broken down into subsections by letters in parentheses (A), (B), and so on. Numbers in parentheses (1), (2), and so forth, may further break down a subsection, and lowercase letters (a), (b), and so on, further break the rule down to the third level. For example, the rule requiring all receptacles in a dwelling unit bathroom to be GFCI protected is contained in Section 210.8(A)(1). Section 210.8(A)(1) is located in Chapter 2, Article 210, Section 8, Subsection (A), Sub-subsection (1).

Many in the industry incorrectly use the term "Article" when referring to a *Code* section. For example, they say "Article 210.8," when they should say "Section 210.8." Section numbers in this book are shown without the word "Section," unless they begin a sentence. For example, Section 210.8(A) is shown as simply 210.8(A).

Tables. Many *Code* requirements are contained within tables, which are lists of *NEC* requirements placed in a systematic arrangement. The titles of the tables are extremely important; you must read them carefully in order to understand the contents, applications, limitations, and so forth, of each table in the *Code*. Many times notes are provided in or below a table; be sure to read them as well since they're also part of the requirement. For example, Note 1 for Table 300.5 explains how to measure the cover when burying cables and raceways, and Note 5 explains what to do if solid rock is encountered.

7. Exceptions. Exceptions are *Code* requirements or permissions that provide an alternative method to a specific requirement. There are two types of exceptions—mandatory and permissive. When a rule has several exceptions, those exceptions with mandatory requirements are listed before the permissive exceptions.

Mandatory Exceptions. A mandatory exception uses the words "shall" or "shall not." The word "shall" in an exception means that if you're using the exception, you're required to do it in a particular way. The phrase "shall not" means it isn't permitted.

Permissive Exceptions. A permissive exception uses words such as "shall be permitted," which means it's acceptable (but not mandatory) to do it in this way.

8. Informational Notes. An Informational Note contains explanatory material intended to clarify a rule or give assistance, but it isn't a *Code* requirement.

9. Annexes. Annexes aren't a part of the *NEC* requirements, and are included in the *Code* for informational purposes only.

Annex A. Product Safety Standards
Annex B. Application Information for Ampacity Calculation
Annex C. Raceway Fill Tables for Conductors and Fixture Wires of the Same Size
Annex D. Examples
Annex E. Types of Construction
Annex F. Critical Operations Power Systems (COPS)
Annex G. Supervisory Control and Data Acquisition (SCADA)
Annex H. Administration and Enforcement
Annex I. Recommended Tightening Torques

10. Index. The Index at the back of the *NEC* is helpful in locating a specific rule.

Changes to the *NEC* since the previous edition(s), are identified by shading, but rules that have been relocated aren't identified as a change. A bullet symbol "•" is located on the margin to indicate the location of a rule that was deleted from a previous edition. New articles contain a vertical line in the margin of the page.

How to Locate a Specific Requirement

How to go about finding what you're looking for in the *Code* depends, to some degree, on your experience with the *NEC*. *Code* experts typically know the requirements so well they just go to the correct rule without any outside assistance. The Table of Contents might be the only thing very experienced *NEC* users need to locate the requirement they're looking for. On the other hand, average *Code* users should use all of the tools at their disposal, including the Table of Contents and the Index.

Table of Contents. Let's work out a simple example: What *NEC* rule specifies the maximum number of disconnects permitted for a service? If you're an experienced *Code* user, you'll know Article 230 applies to "Services," and because this article is so large, it's divided up into multiple parts (actually eight parts). With this knowledge, you can quickly go to the Table of Contents and see it lists the Service Equipment Disconnecting Means requirements in Part VI.

> **Author's Comment:** The number 70 precedes all page numbers because the *NEC* is NFPA Standard Number 70.

Index. If you use the Index, which lists subjects in alphabetical order, to look up the term "service disconnect," you'll see there's no listing. If you try "disconnecting means," then "services," you'll find that the Index specifies that the rule is located in Article 230, Part VI. Because the *NEC* doesn't give a page number in the Index, you'll need to use the Table of Contents to find the page number, or flip through the *Code* to Article 230, then continue to flip through pages until you find Part VI.

Many people complain that the *NEC* only confuses them by taking them in circles. As you gain experience in using the *Code* and deepen your understanding of words, terms, principles, and practices, you'll find the *NEC* much easier to understand and use than you originally thought.

Customizing Your *Code* Book

One way to increase your comfort level with the *Code* is to customize it to meet your needs. You can do this by highlighting and underlining important *NEC* requirements, and by attaching tabs to important pages. Be aware that if you're using your *Code* book to take an exam, some exam centers don't allow markings of any type.

Highlighting. As you read through this textbook, be sure you highlight those requirements in the *Code* that are the most important or relevant to you. Use yellow for general interest and orange for important requirements you want to find quickly. Be sure to highlight terms in the Index and the Table of Contents as you use them.

Underlining. Underline or circle key words and phrases in the *NEC* with a red pen (not a lead pencil) and use a 6-inch ruler to keep lines straight and neat. This is a very handy way to make important requirements stand out. A small 6-inch ruler also comes in handy for locating specific information in the many *Code* tables.

Tabbing the *NEC*. By placing tabs on *Code* articles, sections, and tables, it will make it easier for you to use the *NEC*. However, too many tabs will defeat the purpose. You can order a set of *Code* tabs designed by Mike Holt online at www.MikeHolt.com, or by calling 1.888.NEC.CODE (632.2633).

About the Author

Mike Holt

Mike Holt worked his way up through the electrical trade from an apprentice electrician to become one of the most recognized experts in the world as it relates to electrical power installations. He has worked as a journeyman electrician, master electrician, and electrical contractor. Mike's experience in the real world gives him a unique understanding of how the *NEC* relates to electrical installations from a practical standpoint. You'll find his writing style to be direct, nontechnical, and practical.

Did you know that he didn't finish high school? So if you struggled in high school or if you didn't finish it at all, don't let this get you down, you're in good company. As a matter of fact, Mike Culbreath, Master Electrician, who produces the finest electrical graphics in the history of the electrical industry, didn't finish high school either. So two high school dropouts produced the text and graphics in this textbook! However, realizing success depends on one's continuing pursuit of education. Mike immediately attained his GED (as did Mike Culbreath) and ultimately attended the University of Miami's Graduate School for a Master's degree in Business Administration (MBA).

Mike Holt resides in Central Florida, is the father of seven children, and has many outside interests and activities. He's a six-time National Barefoot Water-Ski Champion (1988, 1999, 2005, 2006, 2007, and 2008), has set many national records, has competed in three World Championships (2006, 2008, and 2010) and continues to train and work out year-round so that he can qualify to ski in the 2012 World Barefoot Championships at the age of 61!

What sets him apart from some, is his commitment to living a balanced lifestyle; placing God first, family, career, then self.

Mike Holt—Special Acknowledgments

First, I want to thank God for my godly wife who's always by my side and my children, Belynda, Melissa, Autumn, Steven, Michael, Meghan, and Brittney.

A special thank you must be sent to the staff at the National Fire Protection Association (NFPA), publishers of the *NEC*—in particular Jeff Sargent for his assistance in answering my many *Code* questions over the years. Jeff, you're a "first class" guy, and I admire your dedication and commitment to helping others understand the *NEC*. Other former NFPA staff members I would like to thank include John Caloggero, Joe Ross, and Dick Murray for their help in the past.

A personal thank you goes to Sarina, my long-time friend and office manager. It's been wonderful working side-by-side with you for over 25 years nurturing this company's growth from its small beginnings.

About the Graphic Illustrator

Mike Culbreath

Mike Culbreath devoted his career to the electrical industry and worked his way up from an apprentice electrician to master electrician. While working as a journeyman electrician, he suffered a serious on-the-job knee injury. With a keen interest in continuing education for electricians, he completed courses at Mike Holt Enterprises, Inc. and then passed the exam to receive his Master Electrician's license. In 1986, after attending classes at Mike Holt Enterprises, Inc., he joined the staff to update material and later studied computer graphics and began illustrating Mike Holt's textbooks and magazine articles. He's worked with the company for almost 25 years and, as Mike Holt has proudly acknowledged, has helped to transform his words and visions into lifelike graphics.

Special Acknowledgments

I want to thank my wonderful children, Dawn and Mac, who have had to put up with me during the *Code* revision seasons.

I would like to thank Steve Arne, our amazing technical editorial director, Eric Stromberg, an electrical engineer and super geek (and I mean that in the most complimentary manner, this guy is brilliant), and Ryan Jackson, an outstanding and very knowledgeable code guy, for helping me keep our graphics as technically correct as possible.

I also want to give a special thank you to Cathleen Kwas for making me look good with her outstanding layout design and typesetting skills. I would also like to acknowledge Belynda Holt Pinto, our Chief Operations Officer and the rest of the outstanding staff at Mike Holt Enterprises, for all the hard work they do to help produce and distribute these outstanding products.

And last but not least, I need to give a special thank you to Mike Holt for not firing me about 25 years ago when I "borrowed" one of his computers and took it home to begin the process of learning how to do computer illustrations. He gave me the opportunity and time needed to develop my computer graphic skills. He's been an amazing friend and mentor since I met him as a student many years ago. Thanks for believing in me and allowing me to be part of the Mike Holt Enterprises family.

Mike Holt Enterprises Team

Editorial Team

I want to thank **Toni Culbreath** and **Barbara Parks** who worked tirelessly to proofread and edit the final stages of this publication. Their attention to detail and dedication to this project is greatly appreciated.

Production Team

I want to thank **Cathleen Kwas** who did the layout and production of this book. Her desire to create the best possible product for our customers is greatly appreciated.

Video Team Members

The following special persons provided assistance in the development of this textbook; particularly in ensuring that the technical content is accurate. In addition, they all provided outstanding technical advice as they served on the video team along with author Mike Holt and a guest appearance by graphic illustrator Mike Culbreath.

Steve Arne
Technical Training Consultant
Arne Electro Tech
Rapid City, S.Dak.
ElectricalMaster.com

Steve Arne has worked in various positions in the electrical industry since 1974 including electrician, electrical contractor, full-time instructor, and department chair in technical postsecondary education. Steve has developed and taught curriculum for many electrical training courses as well as university business and leadership courses. He's completed a Bachelor's degree in Technical Education and a Master's degree in Administrative Studies. Currently, he provides electrician exam prep and continuing education *Code* classes in South Dakota, Wyoming, and surrounding states using Mike Holt's textbooks and material. He enjoys seeing a student's "lights come on" as they come to a point of understanding and have the "ah-ha" experience of learning something new.

Steve has worked for Mike Holt as a technical editor and video team participant since 2002, and used Mike Holt's books in his classes for a number of years before that. Steve is very thankful to have been associated with an industry leader like Mike who provides excellent training products to help students progress in the electrical industry. Steve has been active in the South Dakota Electrical Council, serving on the Board of the Black Hills Chapter in various capacities and is the current Chapter President.

Steve and his wife Deb live in Rapid City, S.Dak. where they're both active in their church and community, and love to spend time with their children and grandchildren. Most of all, Steve and Deb both endeavor to put God first in their lives and in their home.

Victor M. Ammons
Electrical Department Manager
TMG Engineers, Inc.
Edison, New Jersey
tmg-engr.com

Victor Ammons was born in North Carolina, but has lived primarily in New Jersey since the age of five. He spent his high school and college vacation times working in a small, family-owned electrical contracting firm. Vic married Anne, his high school sweetheart, after his sophomore year at North Carolina State University, from which both graduated with honors two years later. After four years in the Army, during which time their first child was born in Germany, Vic and Anne alternated getting MBA degrees. They now have three married children and three grandchildren.

Vic is a licensed electrical contractor and has spent several years running the family contracting business while his father's health declined. He later trained and turned the business over to his brother-in-law and then returned to the engineering field. Vic is a registered Professional Engineer in New Jersey, is LEED accredited, and has served in several officer positions for the local branch of the National Professional Engineers Society. He is now the Electrical Department Manager for TMG Engineers in Edison, New Jersey.

Vic now resides in west central New Jersey in an area with a few dozen families among nearly a thousand acres of woodlands. Yes, there are still woodlands in New Jersey; they haven't gotten around

to paving them all yet. Vic and Anne celebrated their 41th anniversary in 2010, are avid square and round dancers, and are active in several clubs. He's also an amateur beekeeper. Both are active in several capacities in their church.

Ryan Jackson
Electrical Inspector
Draper City, Ut
West Valley City, UT

Ryan Jackson is a combination inspector in the Salt Lake City, Utah, area. He began doing electrical work at the age of 18. At the age of 23 Ryan landed his first job as an electrical inspector, and subsequently became certified in building, plumbing, and mechanical inspection (commercial and residential), as well as building and electrical plan review. Two years after becoming an inspector, he was approached by a friend in the area asking him to fill in at an electrical seminar for him. After his first class he was hooked, and is now a highly sought-after seminar instructor. Ryan has taught in several states, and loves helping people increase their understanding of the *Code*.

In 2005, Ryan met Mike Holt in Salt Lake City, and they became friends immediately. He helped Mike with his *Understanding the NEC, Volume 2* videos and began editing his books as well. Ryan believes that there are only a small handful of opportunities that change a person's life and career, and meeting Mike was one of them.

Ryan can often be found in his garage turning wood on his lathe, and in the autumn you'll find him at as many University of Utah football games as he can attend, which is typically all of them. Ryan married his high school sweetheart, Sharie, and they have two beautiful children together: Kaitlynn and Aaron.

Eric Stromberg
Electrical Engineer/Instructor
Stromberg Engineering, Inc.
Lake Jackson, TX
www.strombergengineering.com

Eric Stromberg started in the Electrical field by working as a journeyman electrician for a small contractor in the Houston area while going to college pursuing a degree in Electrical Engineering. After graduation, in 1982, Eric worked as an electronic technician where he installed and maintained life safety control systems in high rise buildings. In 1989, Eric went to work for Dow Chemical where he designed power distribution systems for major industrial complexes in the U.S., Spain, Brazil, and Germany. Eric was very involved in both creating Electrical standards and procedures as well as checking existing standards and procedures for alignment with national standards.

He also worked as a Construction Manager where he ensured *Code* compliancy of installations as well as provided field engineering support. Eric currently has his own business and spends a good deal of time teaching classes in both the *National Electrical Code* and electrical circuits. He is also a member of the Electrical Safety and Licensing Advisory Board for the State of Texas.

Eric lives in Lake Jackson, Texas, with his wife Jane. They have three children: Ainsley, Austin, and Brieanna. Ainsley is a teacher in Boston who will be getting married in the summer of 2011. Austin will be enlisting in the Air Force, and Brieanna started college in the Fall of 2010.

J. Kevin Vogel
Professional Engineer/Instructor
Crescent Electric Supply
Coeur d'Alene, ID
www.cesco.com and www.trindera.com.

Kevin Vogel graduated from Santa Clara University in 1964 with a Bachelor of Science degree in Mechanical Engineering. A licensed Professional Engineer since 1969, he worked as Chief Engineer for a division of Square D Company that manufactured electric heaters and thermoplastic outlet boxes. He also was employed as an electrician and holds a Master Electrician's license.

In 1978, Kevin co-founded an electrical wholesale distribution business that was acquired in 1991 by Crescent Electric Supply Company. Kevin continues to work in that part of the industry, and is a certified instructor for *National Electrical Code* classes in the states of Idaho and Washington. He also serves as a consultant to Trindera Engineering, an electrical engineering firm located in Coeur d'Alene.

Kevin and his beloved wife Linda have been married since 1966, and have been blessed with 13 wonderful children and 20 (so far) grandchildren. Kevin is extremely grateful to God for all of the gifts He has bestowed on him and his loved ones.

Notes

Note: Hazards in electrical systems often occur because circuits are overloaded or not properly installed in accordance with the *NEC*. These often occur if the initial wiring didn't provide reasonable provisions for system changes or for the increase in the use of electricity.

Author's Comments:

- See the definition of "Overload" in Article 100.
- The *NEC* doesn't require electrical systems to be designed or installed to accommodate future loads. However, the electrical designer, typically an electrical engineer, is concerned with not only ensuring electrical safety (*Code* compliance), but also with ensuring the system meets the customers' needs, both of today and in the near future. To satisfy customers' needs, electrical systems are often designed and installed above the minimum requirements contained in the *NEC*. But just remember, if you're taking an exam, licensing exams are based on your understanding of the minimum Code requirements.

(C) Intention. The *Code* is intended to be used by those skilled and knowledgeable in electrical theory, electrical systems, construction, and the installation and operation of electrical equipment. It isn't a design specification standard or instruction manual for the untrained and unqualified.

(D) Relation to International Standards. The requirements of the *NEC* address the fundamental safety principles contained in the International Electrotechnical Commission (IEC) standards, including protection against electric shock, adverse thermal effects, overcurrent, fault currents, and overvoltage. Figure 90–2

Figure 90–2

Author's Comments:

- See the definition of "Overcurrent" in Article 100.
- The *NEC* is used in Chile, Ecuador, Peru, and the Philippines. It's also the electrical code for Colombia, Costa Rica, Mexico, Panama, Puerto Rico, and Venezuela. Because of these adoptions, the *NEC* is available in Spanish from the National Fire Protection Association, 617.770.3000, or www.NFPA.Org.

90.2 Scope of the *NEC*.

(A) What is Covered. The *NEC* contains requirements necessary for the proper installation of electrical conductors, equipment, and raceways; signaling and communications conductors, equipment, and raceways; as well as optical fiber cables and raceways for the following locations: Figure 90–3

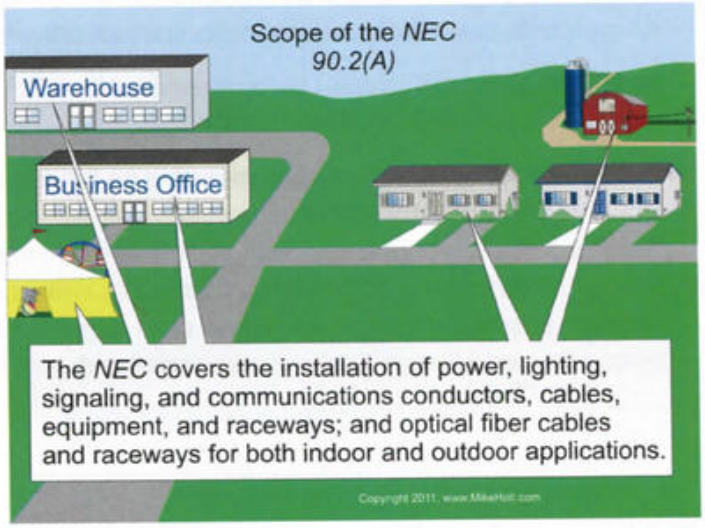


Figure 90–3

(1) Public and private premises, including buildings or structures, mobile homes, recreational vehicles, and floating buildings.

(2) Yards, lots, parking lots, carnivals, and industrial substations.

(3) Conductors and equipment connected to the utility supply.

(4) Installations used by an electric utility, such as office buildings, warehouses, garages, machine shops, recreational buildings, and other electric utility buildings that aren't an integral part of a utility's generating plant, substation, or control center. Figure 90–4

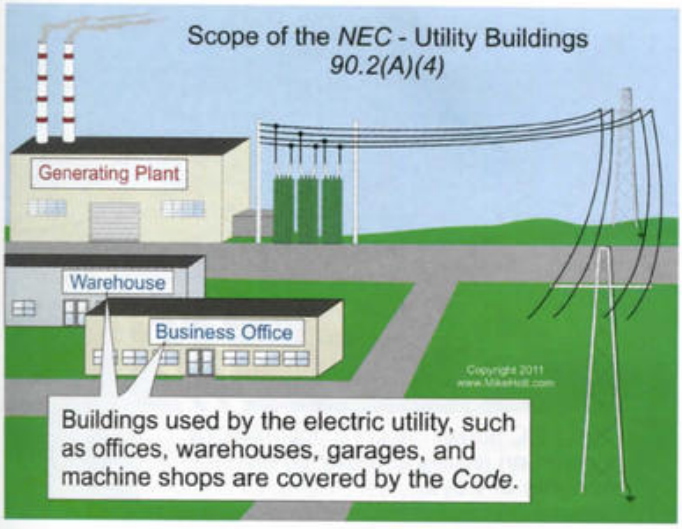


Figure 90–4

(B) What Isn't Covered. The *NEC* doesn't apply to:

(1) Transportation Vehicles. Installations in cars, trucks, boats, ships and watercraft, planes, electric trains, or underground mines.

(2) Mining Equipment. Installations underground in mines and self-propelled mobile surface mining machinery and its attendant electrical trailing cables.

(3) Railways. Railway power, signaling, and communications wiring.

(4) Communications Utilities. The installation requirements of the *NEC* don't apply to communications (telephone), Community Antenna Television (CATV), or network-powered broadband utility equipment located in building spaces used exclusively for these purposes, or outdoors if the installation is under the exclusive control of the communications utility. Figures 90–5 and 90–6

Author's Comment: Interior wiring for communications systems, not in building spaces used exclusively for these purposes, must be installed in accordance with the following Chapter 8 Articles:

- Telephone and Data, Article 800
- CATV, Article 820
- Network-Powered Broadband, Article 830

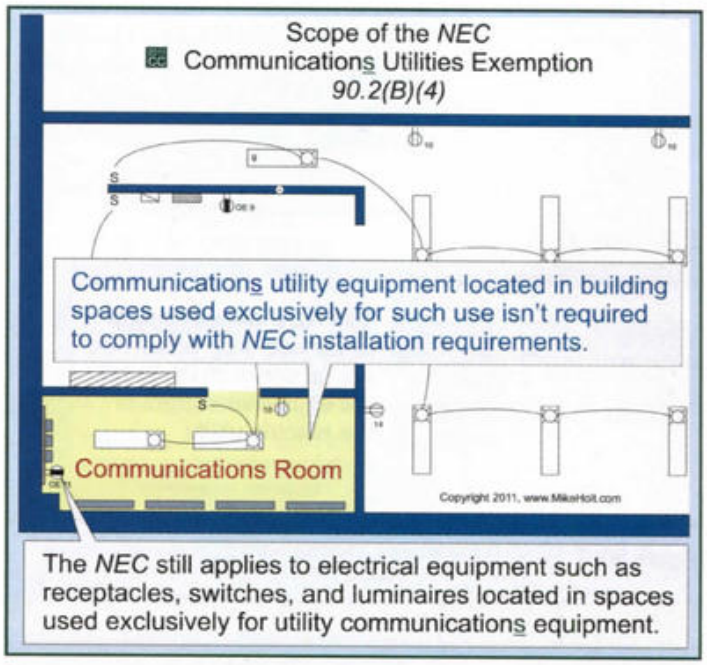


Figure 90–5

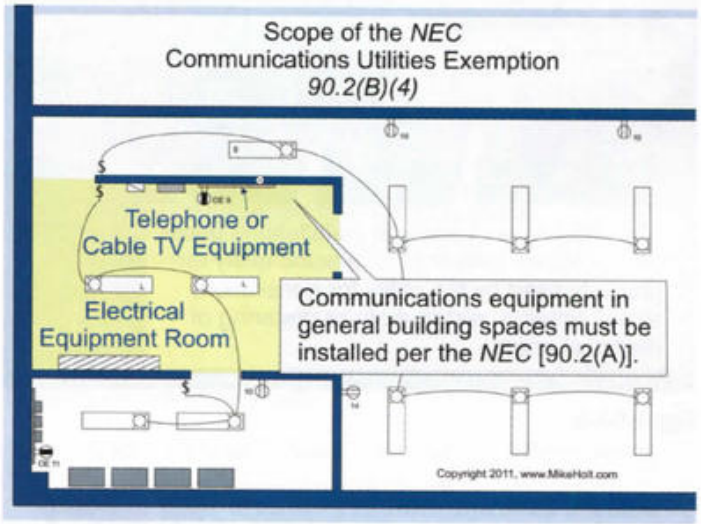


Figure 90–6

(5) Electric Utilities. The *NEC* doesn't apply to installations under the exclusive control of an electric utility where such installations:

a. Consist of service drops or service laterals and associated metering. Figure 90–7

b. Are on property owned or leased by the electric utility for the purpose of generation, transformation, transmission, distribution, or metering of electric energy. Figure 90–8

Code Arrangement
90.3

General Requirements

- Chapter 1 - General
- Chapter 2 - Wiring and Protection
- Chapter 3 - Wiring Methods and Materials
- Chapter 4 - Equipment for General Use

Chapters 1 through 4 generally apply to all applications.

Special Requirements

- Chapter 5 - Special Occupancies
- Chapter 6 - Special Equipment
- Chapter 7 - Special Conditions

Chapters 5 through 7 can supplement or modify the general requirements of Chapters 1 through 4.

- Chapter 8 - Communications Systems

Chapter 8 requirements aren't subject to requirements in Chapters 1 through 7, unless there's a specific reference in Chapter 8 to a rule in Chapters 1 through 7.

- Chapter 9 - Tables

Chapter 9 tables are applicable as referenced in the *NEC* and are used for calculating raceway sizes, conductor fill, and voltage drop.

- Annexes A through I

Annexes are for information only and aren't enforceable.

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Figure 90–10

Special Requirements. The requirements contained in Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions. These chapters can supplement or modify the requirements in Chapters 1 through 4.

Communications Systems. Chapter 8 contains the requirements for communications systems, such as telephone systems, antenna wiring, CATV, and network-powered broadband systems. Communications systems aren't subject to the general requirements of Chapters 1 through 4, or the special requirements of Chapters 5 through 7, unless there's a specific reference in Chapter 8 to a rule in Chapters 1 through 7.

Author's Comment: An example of how Chapter 8 works is in the rules for working space about equipment. The typical 3 ft working space isn't required in front of communications equipment, because Table 110.26(A)(1) isn't referenced in Chapter 8.

Tables. Chapter 9 consists of tables applicable as referenced in the *NEC*. The tables are used to calculate raceway sizing, conductor fill, the radius of raceway bends, and conductor voltage drop.

Annexes. Annexes aren't part of the *Code*, but are included for informational purposes. There are eight Annexes:

- Annex A. Product Safety Standards
- Annex B. Application Information for Ampacity Calculation
- Annex C. Raceway Fill Tables for Conductors and Fixture Wires of the Same Size
- Annex D. Examples
- Annex E. Types of Construction
- Annex F. Critical Operations Power Systems (COPS)
- Annex G. Supervisory Control and Data Acquisition (SCADA)
- Annex H. Administration and Enforcement

90.4 Enforcement. The *Code* is intended to be suitable for enforcement by governmental bodies that exercise legal jurisdiction over electrical installations for power, lighting, signaling circuits, and communications systems, such as: **Figure 90–11**

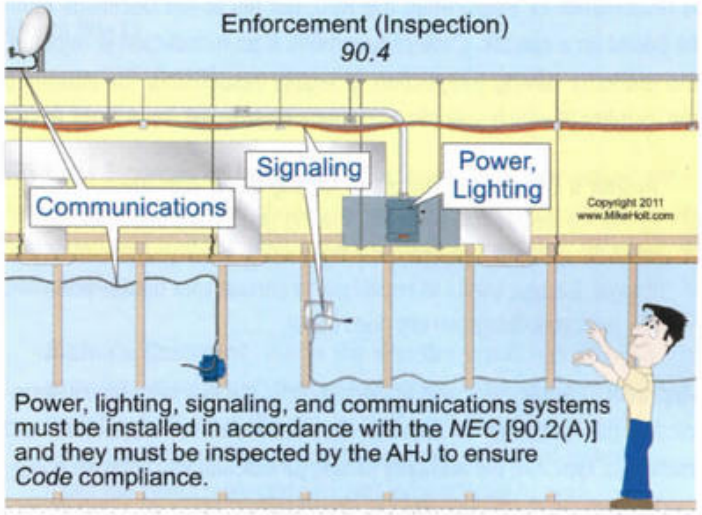

Figure 90–11

Signaling circuits which include:

- Article 725 Class 1, Class 2, and Class 3 Remote-Control, Signaling, and Power-Limited Circuits
- Article 760 Fire Alarm Systems
- Article 770 Optical Fiber Cables and Raceways

Communications systems which include:

- Article 800 Communications Circuits (twisted-pair conductors)
- Article 810 Radio and Television Equipment (satellite dish and antenna)
- Article 820 Community Antenna Television and Radio Distribution Systems (coaxial cable)
- Article 830 Network-Powered Broadband Communications Systems

Author's Comment: The installation requirements for signaling circuits and communications circuits are covered in Mike Holt's *Understanding the National Electrical Code, Volume 2* textbook.

The enforcement of the *NEC* is the responsibility of the authority having jurisdiction (AHJ), who is responsible for interpreting requirements, approving equipment and materials, waiving *Code* requirements, and ensuring equipment is installed in accordance with listing instructions.

Author's Comment: See the definition of "Authority Having Jurisdiction" in Article 100.

Interpretation of the Requirements. The authority having jurisdiction is responsible for interpreting the *NEC*, but his or her decisions must be based on a specific *Code* requirement. If an installation is rejected, the authority having jurisdiction is legally responsible for informing the installer of which specific *NEC* rule was violated.

Author's Comment: The art of getting along with the authority having jurisdiction consists of doing good work and knowing what the *Code* actually says (as opposed to what you only think it says). It's also useful to know how to choose your battles when the inevitable disagreement does occur.

Approval of Equipment and Materials. Only the authority having jurisdiction has authority to approve the installation of equipment and materials. Typically, the authority having jurisdiction will approve equipment listed by a product testing organization, such as Underwriters Laboratories Inc. (UL). The *NEC* doesn't require all equipment to be listed, but many state and local AHJs do. See 90.7, 110.2, 110.3, and the definitions for "Approved," "Identified," "Labeled," and "Listed" in Article 100. Figure 90–12

Author's Comment: According to the *NEC*, the authority having jurisdiction determines the approval of equipment. This means he or she can reject an installation of listed equipment and can approve the use of unlisted equipment. Given our highly litigious society, approval of unlisted equipment is becoming increasingly difficult to obtain.

Waiver of Requirements. By special permission, the authority having jurisdiction can waive specific requirements in the *Code* or permit alternative methods where it's assured equivalent safety can be achieved and maintained.

Author's Comment: Special permission is defined in Article 100 as the written consent of the authority having jurisdiction.

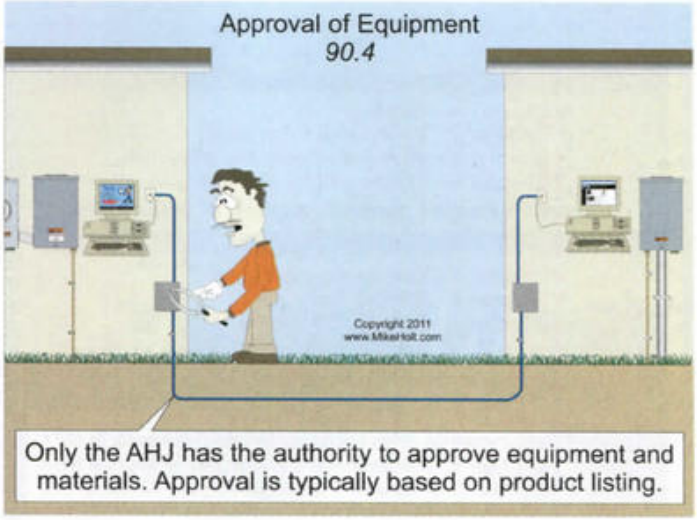

Figure 90–12

Waiver of New Product Requirements. If the 2011 *NEC* requires products that aren't yet available at the time the *Code* is adopted, the authority having jurisdiction can allow products that were acceptable in the previous *Code* to continue to be used.

Author's Comment: Sometimes it takes years before testing laboratories establish product standards for new *NEC* requirements, and then it takes time before manufacturers can design, manufacture, and distribute these products to the marketplace.

90.5 Mandatory Requirements and Explanatory Material.

(A) Mandatory Requirements. In the *NEC* the words "shall" or "shall not," indicate a mandatory requirement.

Author's Comment: For the ease of reading this textbook, the word "shall" has been replaced with the word "must," and the words "shall not" have been replaced with "must not." Remember that in many places, we will paraphrase the *Code* instead of providing exact quotes, to make it easier to read and understand.

(B) Permissive Requirements. When the *Code* uses "shall be permitted" it means the identified actions are permitted but not required, and the authority having jurisdiction isn't permitted to restrict an installation from being done in that manner. A permissive rule is often an exception to the general requirement.

Author's Comment: For ease of reading, the phrase "shall be permitted," as used in the *Code*, has been replaced in this textbook with the phrase "is permitted" or "are permitted."

(C) Explanatory Material. References to other standards or sections of the *NEC*, or information related to a *Code* rule, are included in the form of Informational Notes. Such notes are for information only and aren't enforceable as a requirement of the *NEC*.

For example, Informational Note 4 in 210.19(A)(1) recommends that the voltage drop of a circuit not exceed 3 percent. This isn't a requirement; it's just a recommendation.

Author's Comment: For convenience and ease of reading in this textbook, I will identify Informational Notes simply as "Note."

(D) Informative Annexes. Nonmandatory information annexes contained in the back of the *Code* book are for information only and aren't enforceable as a requirement of the *NEC*.

90.6 Formal Interpretations. To promote uniformity of interpretation and application of the provisions of the *NEC*, formal interpretation procedures have been established and are found in the NFPA Regulations Governing Committee Projects.

Author's Comment: This is rarely done because it's a very time-consuming process, and formal interpretations from the NFPA aren't binding on the authority having jurisdiction.

90.7 Examination of Equipment for Product Safety.

Product evaluation for safety is typically performed by a testing laboratory, which publishes a list of equipment that meets a nationally recognized test standard. Products and materials that are listed, labeled, or identified by a testing laboratory are generally approved by the authority having jurisdiction.

Author's Comment: See Article 100 for the definition of "Approved."

Listed, factory-installed, internal wiring and construction of equipment need not be inspected at the time of installation, except to detect alterations or damage [300.1(B)]. Figure 90–13

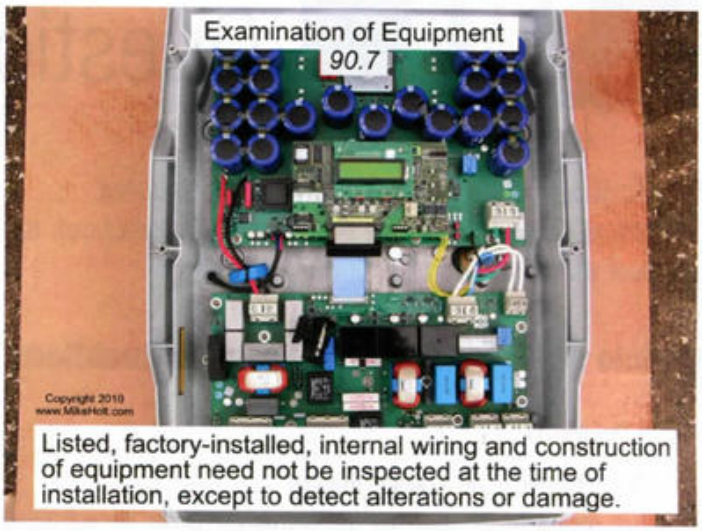

Figure 90–13

90.9 Units of Measurement.

(B) Dual Systems of Units. Both the metric and inch-pound measurement systems are shown in the *NEC*, with the metric units appearing first and the inch-pound system immediately following in parentheses.

Author's Comment: This is the standard practice in all NFPA standards, even though the U.S. construction industry uses inch-pound units of measurement. You will need to be cautious when using the tables in the *Code* because the additional units can make the tables more complex and more difficult to read.

(D) Compliance. Installing electrical systems in accordance with the metric system or the inch-pound system is considered to comply with the *Code*.

Author's Comment: Since compliance with either the metric or the inch-pound system of measurement constitutes compliance with the *NEC*, this textbook uses only inch-pound units.

ARTICLE 90 Practice Questions

These questions are based on the 2011 *National Electrical Code*. Please use the 2011 *NEC Code* book to answer the following questions.

Article 90. Introduction—Practice Questions

1. The *NEC* is _____.

   (a) intended to be a design manual
   (b) meant to be used as an instruction guide for untrained persons
   (c) for the practical safeguarding of persons and property
   (d) published by the Bureau of Standards

2. Hazards often occur because of _____.

   (a) overloading of wiring systems by methods or usage not in conformity with the *NEC*
   (b) initial wiring not providing for increases in the use of electricity
   (c) a and b
   (d) none of these

3. This *Code* covers the installation of _____ for public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings.

   (a) optical fiber cables
   (b) electrical equipment
   (c) raceways
   (d) all of these

4. Installations of communications equipment that are under the exclusive control of communications utilities, and located outdoors or in building spaces used exclusively for such installations _____ covered by the *NEC*.

   (a) are
   (b) are sometimes
   (c) are not
   (d) may be

5. Utilities may be subject to compliance with codes and standards covering their regulated activities as adopted under governmental law or regulation.

   (a) True
   (b) False

6. Communications wiring such as telephone, antenna, and CATV wiring within a building shall not be required to comply with the installation requirements of Chapters 1 through 7, except where specifically referenced in Chapter 8.

   (a) True
   (b) False

7. The _____ has the responsibility for deciding on the approval of equipment and materials.

   (a) manufacturer
   (b) authority having jurisdiction
   (c) testing agency
   (d) none of these

8. The authority having jurisdiction has the responsibility for _____.

   (a) making interpretations of rules
   (b) deciding upon the approval of equipment and materials
   (c) waiving specific requirements in the *Code* and permitting alternate methods and material if safety is maintained
   (d) all of these

9. When the *Code* uses "_____," it means the identified actions are allowed but not required, and they may be options or alternative methods.

   (a) shall
   (b) shall not
   (c) shall be permitted
   (d) a or b

10. Explanatory material, such as references to other standards, references to related sections of the *NEC*, or information related to a *Code* rule, are included in the form of Informational Notes.

    (a) True
    (b) False

Notes